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# VIRTUAL MEMORY MANAGEMENT

Virtual memory is a way for computers to temporarily move data from the main memory (RAM) to a storage device (like a hard drive) to free up space when there's not enough memory to run multiple programs at the same time. By mapping chunks of memory to disk files, the computer can treat the secondary memory as if it were the main memory. This is important because most personal computers come with at least 8 GB of RAM, but sometimes this isn't enough to run all the programs a user needs. Virtual memory solves this problem by swapping out data that hasn't been used recently, freeing up space in the RAM for other programs to use.

## THRASHING

Virtual memory is a helpful feature that helps to boost a computer's performance when running large programs or multitasking. But, relying too much on virtual memory can slow down the system, since it is slower than RAM. When the operating system has to constantly swap data between virtual memory and RAM, it can cause the computer to slow down significantly, which is referred to as thrashing. To avoid thrashing, it's important to ensure that the computer has enough physical memory (RAM) to support the tasks being performed.

## WHY VIRTUAL MEMORY?

Virtual memory was created to solve the problem of limited physical memory (RAM) in computers, which was expensive at the time. When multiple programs run simultaneously, the available RAM may become insufficient, causing the system to slow down or crash. Virtual memory uses a portion of the hard drive to simulate additional RAM, allowing larger or multiple programs to run smoothly without requiring more physical memory. This makes it possible for a computer to operate as if it has more space, without the need to purchase more expensive RAM.

## HOW VIRTUAL MEMORY WORKS?

Virtual memory uses both hardware and software to help a computer run more programs than it has physical RAM for. When you open a program, data is stored in physical memory using RAM. The computer's Memory Management Unit maps this address to RAM and translates addresses. If the RAM space is needed for something more important, data can be swapped out of RAM and into virtual memory. The computer's memory manager keeps track of the shifts between physical and virtual memory.

The OS divides memory with a fixed number of addresses into pagefiles or swap files, each stored on a disk. When the page is needed, the OS copies it from the disk to main memory and translates the virtual addresses into real addresses. But, this process of swapping virtual memory to physical is slow and can lead to a reduction in performance. So, having more physical RAM is better for computer performance.

# TYPES OF VIRTUAL MEMORY MANAGEMENT

## DEMAND PAGING

There are different types of virtual memory management, and one of them is demand paging. This technique divides the computer's memory into sections or paging files. When the available RAM is used up, pages that are not currently in use are moved to a swap file on the hard drive, which acts as an extension of the computer's RAM.

When the swap file is needed again, a process called page swapping is used to transfer the data back to RAM. This system ensures that the operating system and applications have enough memory to perform their tasks without running out of space. By using demand paging, the computer can effectively manage its memory usage and prevent crashes or slowdowns due to insufficient RAM.

## SEGMENTATION

Segmentation is another way of managing virtual memory. Instead of dividing memory into fixed-size pages, segmentation divides it into variable-length segments. Unused segments can be moved to virtual memory on the hard drive. A segment table is used to keep track of segmented data or processes in memory, showing whether a segment is present in memory, whether it has been modified, and its physical address. Moreover, the file system in segmentation is composed of only segments that are mapped into a process's potential address space.

## PAGING VS SEGMENTATION

Paging and segmentation are two different ways to manage virtual memory. In paging, memory is divided into small sections called pages, while in segmentation, memory is divided into larger sections called segments.

Sometimes, these two approaches are combined. In this case, memory is divided into pages, and each segment takes up multiple pages. This helps the computer manage its memory usage more efficiently by keeping track of different segments of data.

This technique is important because it helps prevent crashes and slowdowns by ensuring that the operating system and applications have enough memory to perform their tasks effectively.

## ADVANTAGES OF USING VMM

Using virtual memory management (VMM) has several advantages. Firstly, it allows a computer to handle twice as many addresses as its physical memory (RAM), enabling more applications to be used at once.

VMM also frees up applications from managing shared memory, which saves users from having to add memory modules when RAM space runs out. Additionally, VMM can increase the speed of execution when only a segment of a program is needed.

Security is another advantage of VMM, as it provides memory isolation. Multiple larger applications can run simultaneously, and allocating memory is relatively inexpensive. VMM also does not require external fragmentation and is effective for managing logical partition workloads.

Finally, data can be moved automatically, and pages in the original process can be shared during a fork system call operation that creates a copy of itself. Overall, using VMM can significantly improve a computer's performance and efficiency.

## LIMITATIONS

Although virtual memory has many advantages, there are also some limitations to consider. Firstly, applications running from virtual memory may run slower than those running from physical memory. Secondly, mapping data between virtual and physical memory requires additional hardware support for address translations, which can further slowdown a computer. The amount of virtual storage available is limited by the amount of secondary storage and addressing scheme used by the computer system. If there is not enough RAM, thrashing can occur, which will cause the computer to perform slower. Additionally, switching between applications using virtual memory may take more time, and it can also reduce the amount of available hard drive space.

## PAGE FAULT

A page fault happens when a program needs data that is not currently in the computer's main memory, and the operating system needs to move it from the hard drive to the memory when it is needed. When the program accesses a memory page that is mapped into the virtual address space but not loaded in physical memory, the MMU sends a page fault exception to the OS to handle it. Because virtual memory is much larger than physical memory, page faults can occur frequently. When a page fault occurs, the OS may have to replace an existing page in memory with the one needed. Different algorithms are used to decide which page to replace in order to minimize the number of page faults.

# PAGE REPLACEMENT ALGORITHMS

## First In First Out (FIFO):

The First In First Out (FIFO) algorithm is a simple page replacement algorithm. The operating system maintains a queue of all the pages in memory, with the oldest page at the front of the queue. When a page needs to be replaced, the one at the front of the queue is selected for removal. This algorithm is based on the number of frames used, and each frame is assigned a certain page that it tries to access. When the frames are full, the algorithm uses the oldest frame to replace the new incoming page. This process is known as Demand Paging. The FIFO algorithm is the first basic algorithm used for page replacement.

### Belady’s anomaly

Belady’s anomaly is a phenomenon that shows that increasing the number of page frames while using the First in First Out (FIFO) page replacement algorithm can result in more page faults. This means that when a larger number of page frames are allocated to a process, it may experience more page faults than when fewer page frames are allocated.